Attachment II: Example of Low Earth Orbit (LEO) - Geostationary Earth Orbit (GEO) simulation.

This attachment applies the geometric analysis defined in this simulation to interference analysis that computes the percent time that I_0/N_0 is above a certain level. The two examples presented in this appendix are for the LEO IRIDIUM® system and the GEO systems SPACEWAY and COMETS.

A: IRIDIUM and COMETS.

The input parameters for the constellations are:

Table 1: IRIDIUM and COMETS simulation input parameters

Input Parameter	IRIDIUM	COMETS
Number of Satellites	66	1
Number of Planes	6	1
Orbit altitude (km)	780.6	35785.4
Inclination (deg)	84.6	0
Right ascension of ascending node (deg)	0.0, 31.6, 63.2, 94.8, 126.4, 158.0	121
Anomaly of first satellite in each plane (deg)	0.0, 16.35, 2.6, 18.95, 5.2, 21.55	0
Minimum elevation (deg)	5	-
Space vehicle maximum transmit gain (dBi)	26.9	48.5
Space vehicle maximum receive gain (dBi)	30.1	52.0
Ground Station North Latitude (deg)	35.5	36
Ground Station West Longitude (deg)	-137	-139
Ground station maximum transmit gain (dBi)	56.3	67.5
Ground station maximum receive gain (dBi)	53.2	63.8

Table 2 shows the Radio Frequency parameters for IRIDIUM and COMETS links.

Table 2: System Radio Frequency Parameters

Parameter	IRIDIUM Space Vehicle	IRIDIUM Ground Station	COMETS Space Vehicle	COMETS Ground Station
P_t/BW_{tx}	-77.8	-76.7	-47.7	-48.5
Transmit λ (m)	0.0154	0.0103	0.0154	0.0103
T (deg K)	1295.4	731.4	2091	200

Table 3 shows the scale factor $\frac{P_t}{BW_{tx}}\frac{\lambda^2}{4\pi}\frac{1}{kT}$ used to convert from the gain range produce to I_0/N_0 and the maximum I_0/N_0 than can occur.

Table 3: $\frac{P_t}{BW_{tx}}\frac{\lambda^2}{4\pi}\frac{1}{kT}$ for the four possible interference paths

Interference Path	$\frac{P_t}{BW_{tx}}\frac{\lambda^2}{4\pi}\frac{1}{kT}$ (dB-m^2)	$\max\frac{G_t(\varphi_1)G_r(\varphi_2)}{4\pi R^2}$ (dB/m^2)	$\max\frac{I_0}{N_0}$ (dB)
IRIDIUM Downlink -> COMETS Downlink	80.5	-51.3	29.2
IRIDIUM Uplink -> COMETS Uplink	67.9	-58.4	9.5
COMETS Downlink -> IRIDIUM Downlink	105.0	-62.6	42.4
COMETS Uplink -> IRIDIUM Uplink	98.2	-47.8	50.4

Figures 3-6 show the I_0/N_0 between IRIDIUM and COMETS for a simulation time of 365 days sampled every 10 seconds. Table 4 shows the percent time that $I_0/N_0 \le -1$ dB.

Table 4: Percent time that $I_0/N_0 \le -1$ dB for the four possible interference paths

Interference Path	% time
IRIDIUM Downlink -> COMETS Downlink	0.007
IRIDIUM Uplink -> COMETS Uplink	>0.001
COMETS Downlink -> IRIDIUM Downlink	0.585
COMETS Uplink -> IRIDIUM Uplink	0.200

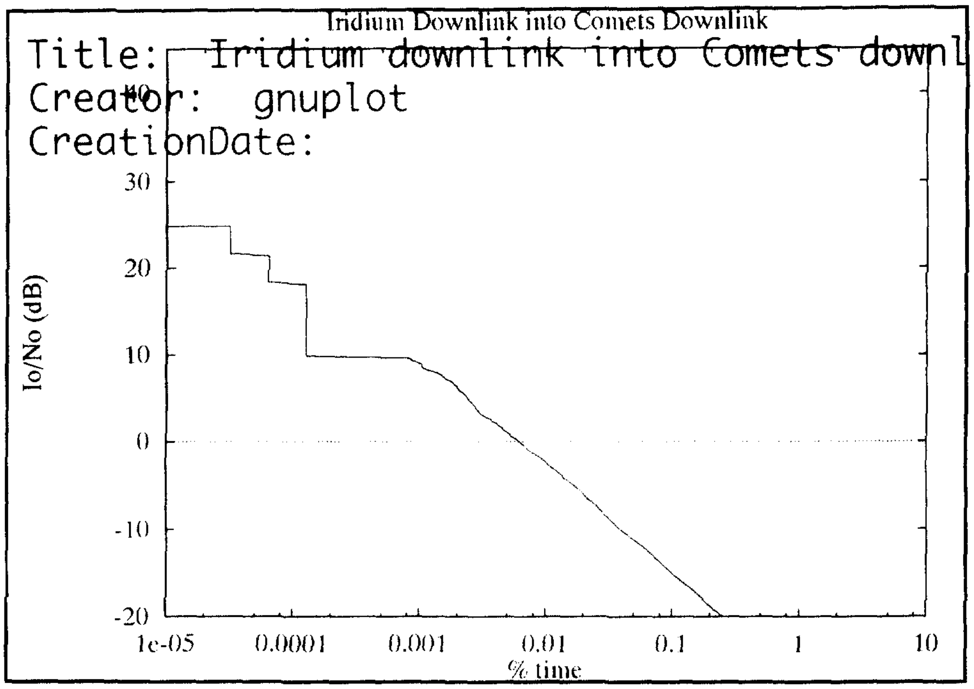


Figure 3. I_0/N_0 for IRIDIUM downlink into COMETS downlink.

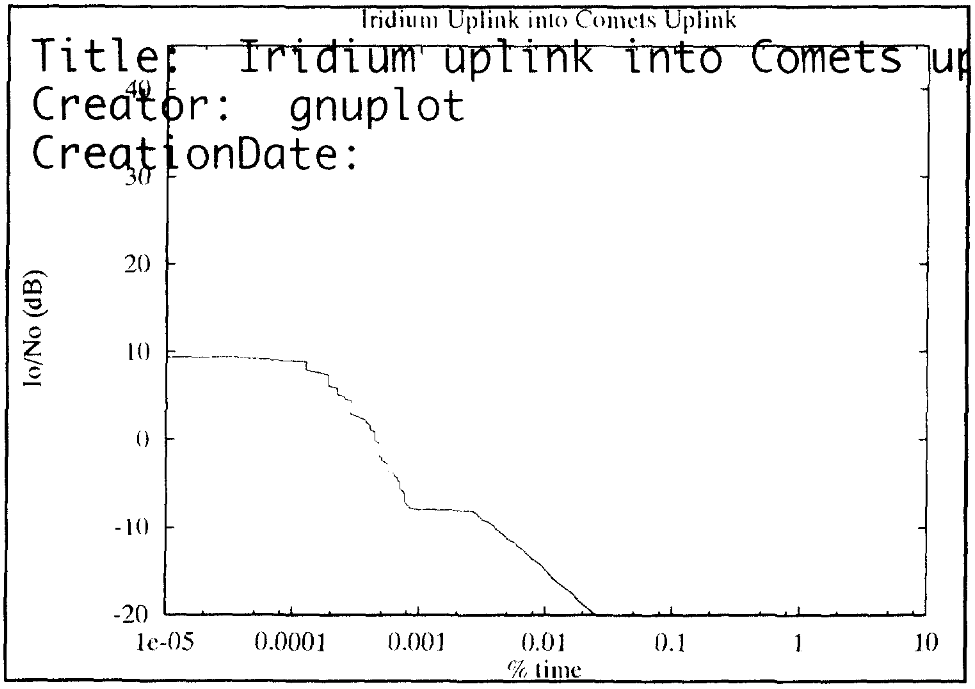


Figure 4. I_0/N_0 for IRIDIUM uplink into COMETS uplink.

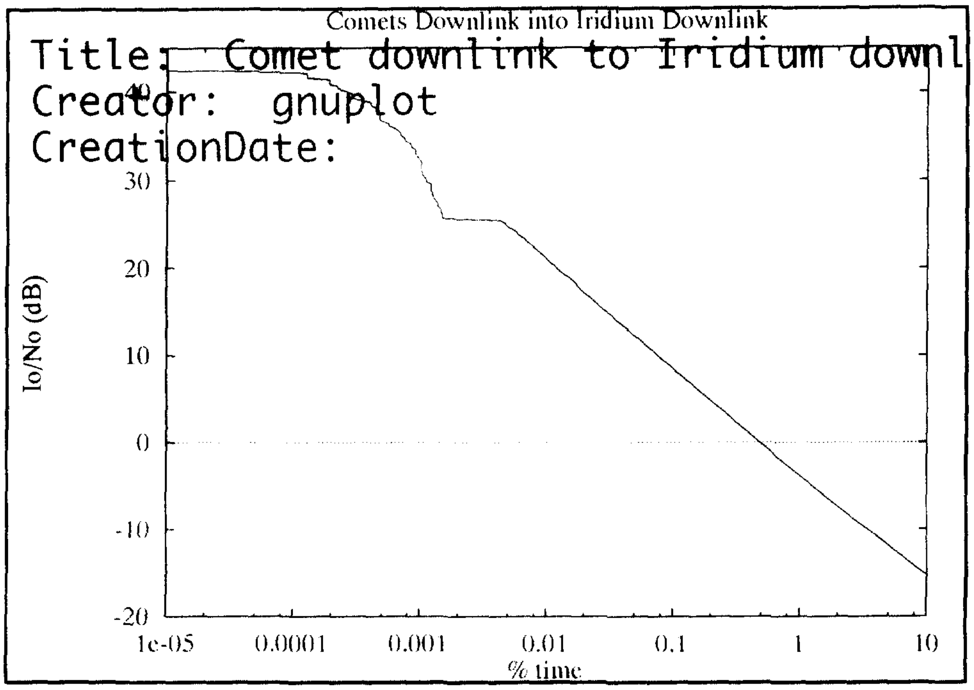


Figure 5. I_0/N_0 for COMETS downlink into IRIDIUM downlink.

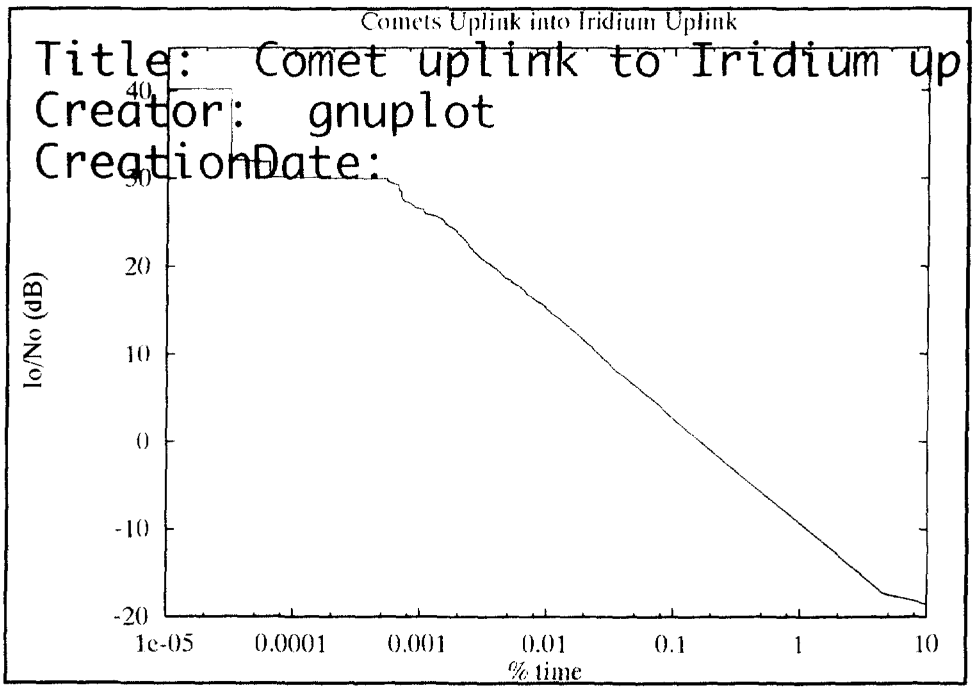


Figure 6. I_0/N_0 for COMETS uplink into IRIDIUM uplink.

B: IRIDIUM and SPACEWAYS (Small Terminals)
This analysis is for the "spot" beams from SPACEWAY (1 degree beams) communicating with the small terminals (66 cm diameter). The input parameters for the constellations are:

Table 5: IRIDIUM and SPACEWAY simulation input parameters

Input Parameter	IRIDIUM	SPACEWAY
Number of Satellites	66	1
Number of Planes	6	1
Orbit altitude (km)	780.6	35785.4
Inclination (deg)	84.6	0
Right ascension of ascending node (deg)	0.0, 31.6, 63.2, 94.8, 126.4, 158.0	-101
Anomaly of first satellite in each plane (deg)	0.0, 16.35, 2.6, 18.95, 5.2, 21.55	0
Minimum elevation (deg)	5	-
Space vehicle maximum transmit gain (dBi)	26.9	46.5
Space vehicle maximum receive gain (dBi)	30.1	46.5
Ground Station North Latitude (deg)	34, 35, 35.5, 36, 37	34
Ground Station West Longitude (deg)	113	113
Ground station maximum transmit gain (dBi)	56.3	44.5
Ground station maximum receive gain (dBi)	53.2	43.0

Table 6 shows the Radio Frequency parameters for IRIDIUM and SPACEWAY links.

Table 6: System Radio Frequency Parameters

Parameter	IRIDIUM Space Vehicle	IRIDIUM Ground Station	SPACEWAY Space Vehicle	SPACEWAY Ground Station
P_t (dBW)	-12.9	-11.8	13.0	-4.7
BW_{tx} (MHz)	3.09	3.09	120	0.5
P_t / BW_{tx}	-77.8	-76.7	-67.8	-61.7
Transmit λ (m)	0.0154	0.0103	0.0154	0.0103
T (deg K)	1295.4	731.4	575	275

Table 7 shows the scale factor $\frac{P_t}{BW_{tx}} \frac{\lambda^2}{4\pi} \frac{1}{kT}$ used to convert from the gain range produce to I_0 / N_0 .

Table 7: $\frac{P_t}{BW_{tx}} \frac{\lambda^2}{4\pi} \frac{1}{kT}$ for the four possible interference paths

Interference Path	$\frac{P_t}{BW_{tx}} \frac{\lambda^2}{4\pi} \frac{1}{kT}$ (dB-m^2)
IRIDIUM Downlink -> SPACEWAY Downlink	79.2
IRIDIUM Uplink -> SPACEWAY Uplink	73.6
SPACEWAY Downlink -> IRIDIUM Downlink	84.9
SPACEWAY Uplink -> IRIDIUM Uplink	85.0

Table 8 shows the maximum interference level that can be computed for the four interference paths.

Table 8: Maximum I_0/N_0 for the four possible interference paths

Interference Path \ Ground Station Latitude (deg)	34 N	35 N	35.5 N	36 N	37 N
IRIDIUM Downlink -> SPACEWAY Downlink	18.0	13.6	8.8	7.5	6.6
IRIDIUM Uplink -> SPACEWAY Uplink	14.0	13.6	13.2	12.6	11.0
SPACEWAY Downlink -> IRIDIUM Downlink	22.2	21.8	21.4	20.8	19.2
SPACEWAY Uplink -> IRIDIUM Uplink	28.6	19.3	17.3	16.0	12.4

Figures 7-10 show the I_0/N_0 between IRIDIUM and SPACEWAY for a simulation time of 85 days sampled every 6 seconds. Table 9 shows the percent time that $I_0/N_0 \leq -1$ dB.

Table 9: Percent time that $I_0/N_0 \leq -1$ dB for the four possible interference paths

Interference Path \ Ground Station Latitude (deg)	34 N	35 N	35.5 N	36 N	37 N
IRIDIUM Downlink -> SPACEWAY Downlink	0.0648	0.0267	0.0100	0.0089	0.0081
IRIDIUM Uplink -> SPACEWAY Uplink	0.0007	0.0006	0.0006	0.0007	0.0007
SPACEWAY Downlink -> IRIDIUM Downlink	0.0132	0.0127	0.0119	0.0105	0.0079
SPACEWAY Uplink -> IRIDIUM Uplink	0.2954	0.0507	0.0339	0.0272	0.0096

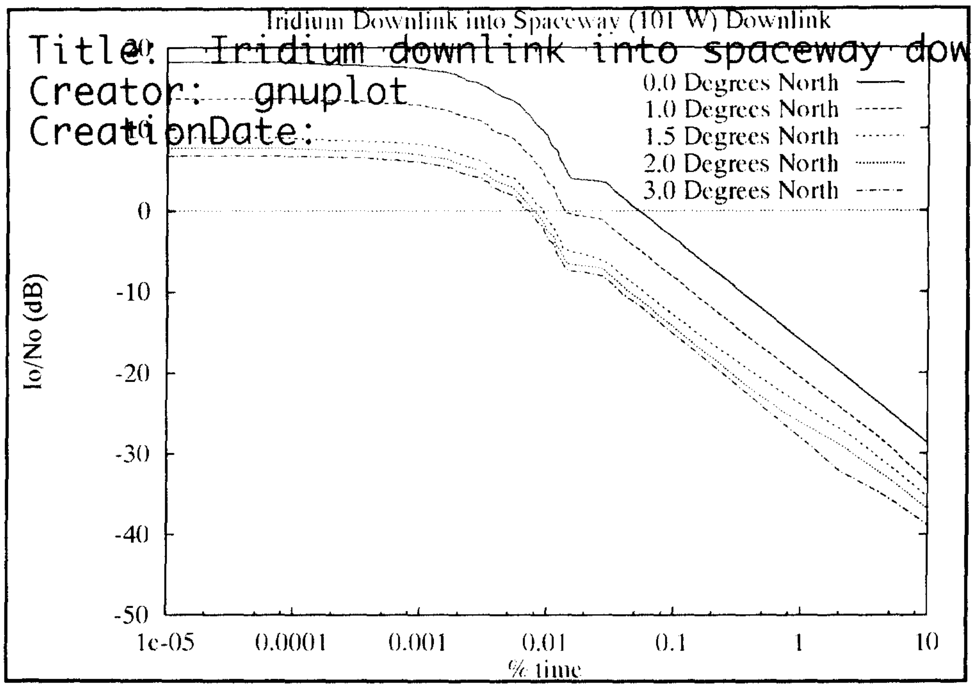


Figure 7. I_0/N_0 for IRIDIUM downlink into SPACEWAY downlink.

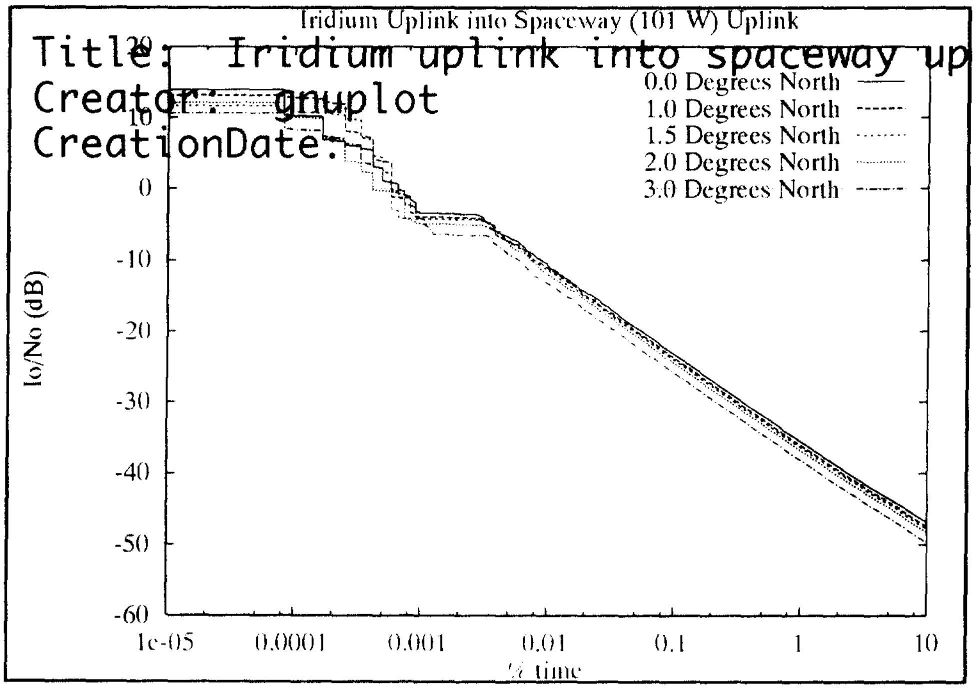


Figure 8. I_0/N_0 for IRIDIUM uplink into SPACEWAY uplink.

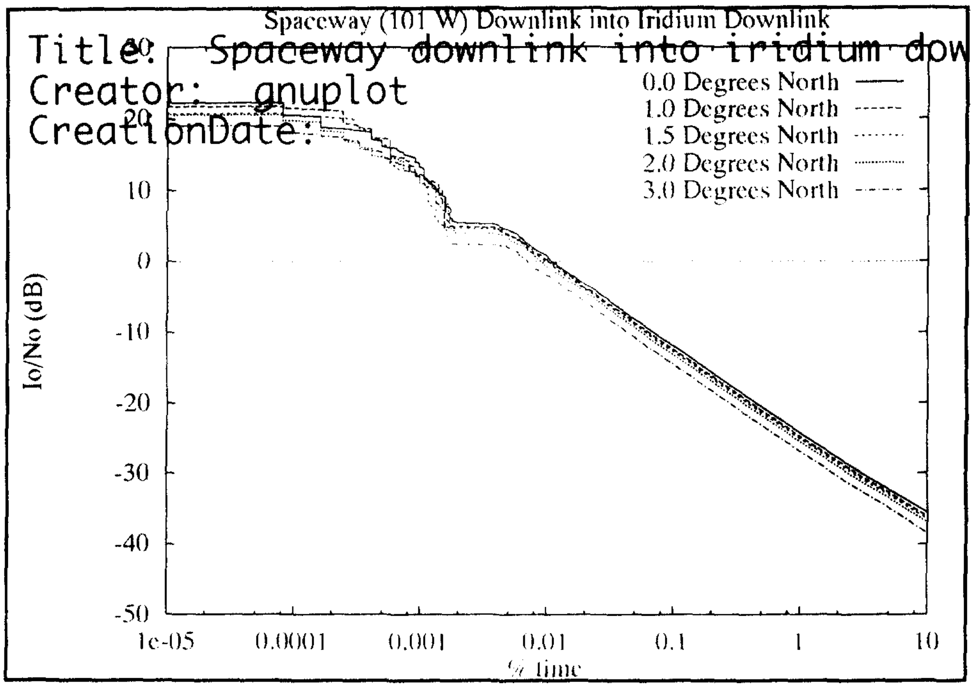


Figure 9. I_0/N_0 for SPACEWAY downlink into IRIDIUM downlink.

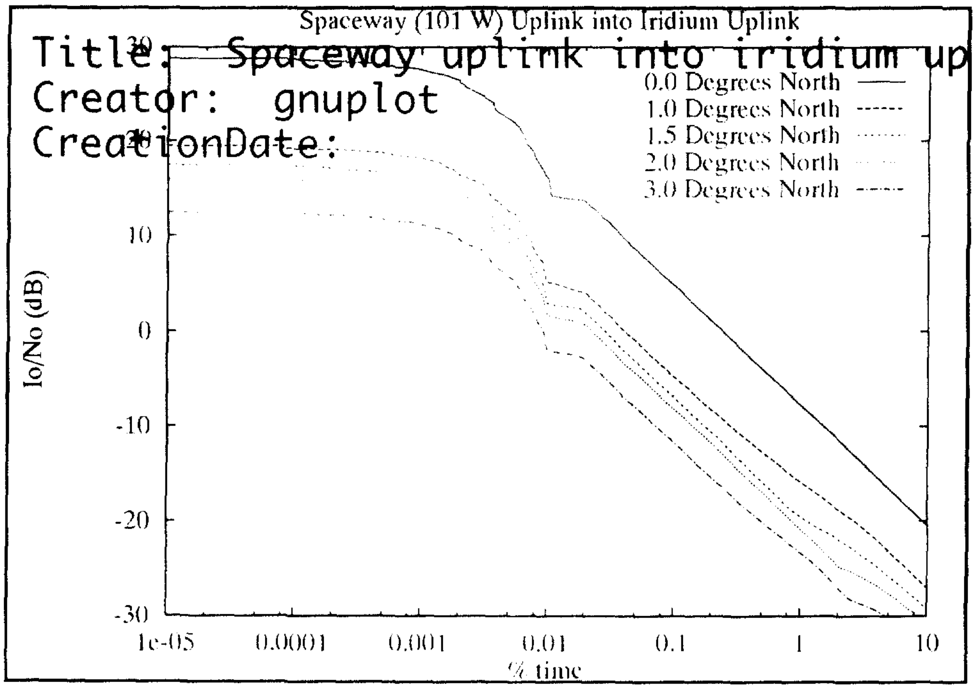


Figure 10. I_0/N_0 for SPACEWAY uplink into IRIDIUM uplink.

IRIDIUM and SPACEWAYS (Large Terminals)

This analysis is for the 3° beams from SPACEWAY communicating with the large terminals (182 cm diameter). The input parameters for the constellations are:

Table 10: IRIDIUM and SPACEWAY simulation input parameters

Input Parameter	IRIDIUM	SPACEWAY
Number of Satellites	66	1
Number of Planes	6	1
Orbit altitude (km)	780.6	35785.4
Inclination (deg)	84.6	0
Right ascension of ascending node (deg)	0.0, 31.6, 63.2, 94.8, 126.4, 158.0	-101
Anomaly of first satellite in each plane (deg)	0.0, 16.35, 2.6, 18.95, 5.2, 21.55	0
Minimum elevation (deg)	5	-
Space vehicle maximum transmit gain (dBi)	26.9	35.02
Space vehicle maximum receive gain (dBi)	30.1	35.0
Ground Station North Latitude (deg)	34, 35, 35.5, 36, 37	34
Ground Station West Longitude (deg)	113	113
Ground station maximum transmit gain (dBi)	56.3	53.3
Ground station maximum receive gain (dBi)	53.2	51.8

Table 11 shows the Radio Frequency parameters for IRIDIUM and SPACEWAY links.

Table 11: System Radio Frequency Parameters

Parameter	IRIDIUM Space Vehicle	IRIDIUM Ground Station	SPACEWAY Space Vehicle	SPACEWAY Ground Station
P_t (dBW)	-12.9	-11.8	17.8	-9.7
BW_{tx} (MHz)	3.09	3.09	120	0.5
P_t/BW_{tx}	-77.8	-76.7	-63.0	-66.7
Transmit λ (m)	0.0154	0.0103	0.0154	0.0103
T (deg K)	1295.4	731.4	575	275

$\frac{P_t}{BW_{tx}} \frac{\lambda^2}{4\pi} \frac{1}{kT}$ used to convert from the gain range produce to I_0/N_0.

Table 12: $\frac{P_t}{BW_{tx}}\frac{\lambda^2}{4\pi}\frac{1}{kT}$ for the four possible interference paths

Interference Path	$\frac{P_t}{BW_{tx}}\frac{\lambda^2}{4\pi}\frac{1}{kT}$ (dB-m^2)
IRIDIUM Downlink -> SPACEWAY Downlink	79.2
IRIDIUM Uplink -> SPACEWAY Uplink	73.6
SPACEWAY Downlink -> IRIDIUM Downlink	89.7
SPACEWAY Uplink -> IRIDIUM Uplink	80.0

Table 13 shows the maximum interference level that can be computed for the four interference paths.

Table 13: Maximum I_0/N_0 for the four possible interference paths

Interference Path \ Ground Station Latitude (deg)	34 N	35 N	35.5 N	36 N	37 N
IRIDIUM Downlink -> SPACEWAY Downlink	26.8	22.6	17.5	16.3	15.1
IRIDIUM Uplink -> SPACEWAY Uplink	2.3	2.1	1.8	1.4	1.4
SPACEWAY Downlink -> IRIDIUM Downlink	15.6	15.3	15.2	15.1	15.0
SPACEWAY Uplink -> IRIDIUM Uplink	32.3	23.0	21.0	19.8	16.0

Figures 11-14 show the I_0/N_0 between IRIDIUM and SPACEWAY for a simulation time of 85 days sampled every 6 seconds. Table 14 shows the percent time that $I_0/N_0 \leq -1$ dB.

Table 14: Percent time that $I_0/N_0 \leq -1$ dB for the four possible interference paths

Interference Path \ Ground Station Latitude (deg)	34 N	35 N	35.5 N	36 N	37 N
IRIDIUM Downlink -> SPACEWAY Downlink	0.0410	0.0170	0.0072	0.0058	0.0038
IRIDIUM Uplink -> SPACEWAY Uplink	0.0002	0.0002	0.0003	0.0002	0.0001
SPACEWAY Downlink -> IRIDIUM Downlink	0.0018	0.0017	0.0015	0.0017	0.0016
SPACEWAY Uplink -> IRIDIUM Uplink	0.0860	0.0145	0.0098	0.0081	0.0039

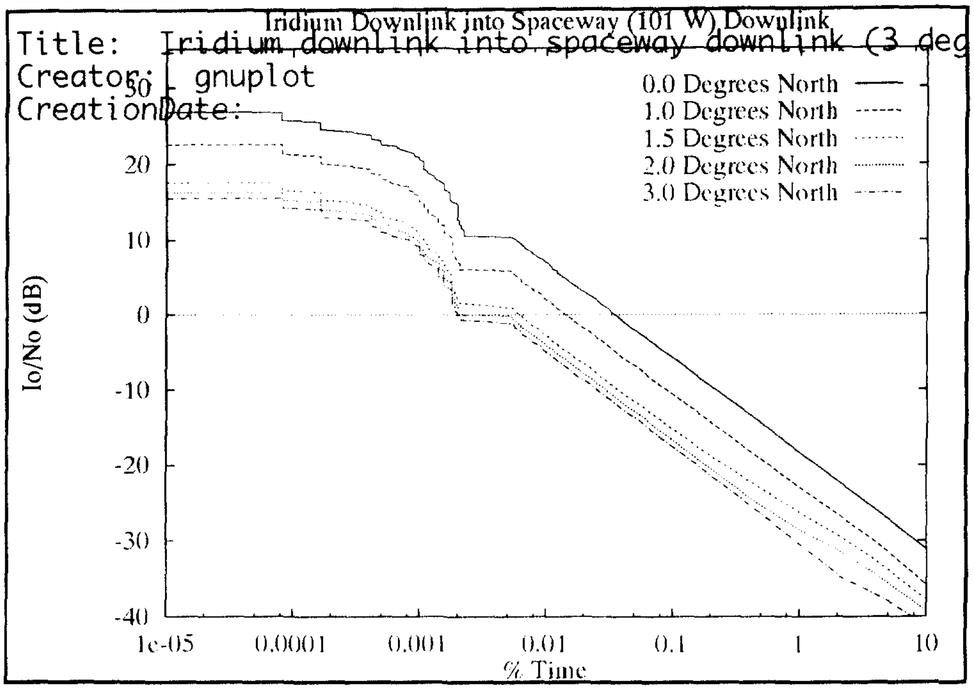


Figure 11. I_0/N_0 for IRIDIUM downlink into SPACEWAY downlink.

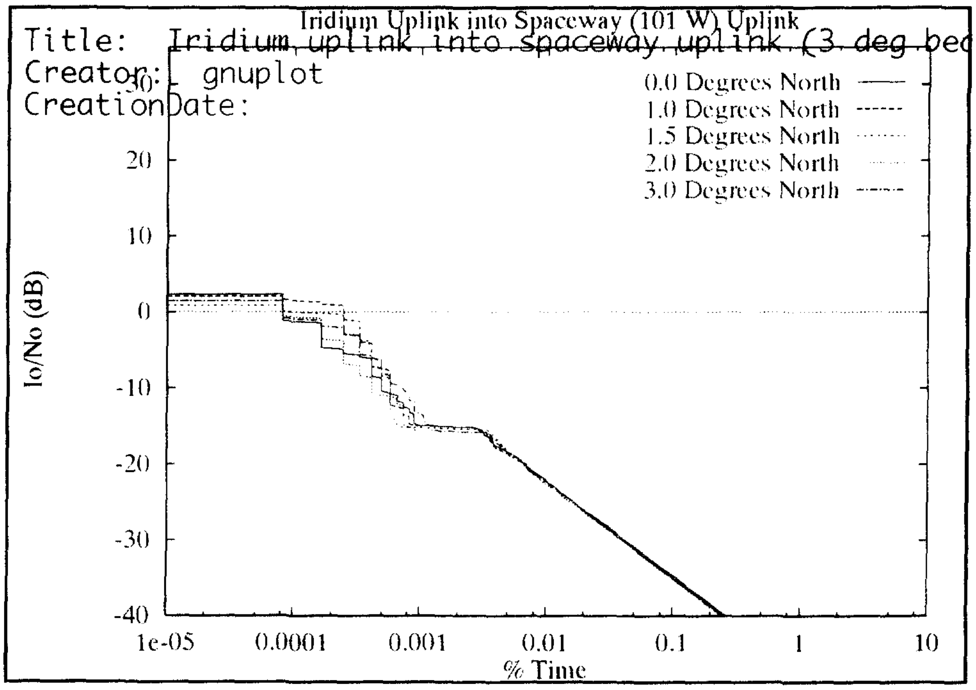


Figure 12. I_0/N_0 for IRIDIUM uplink into SPACEWAY uplink.

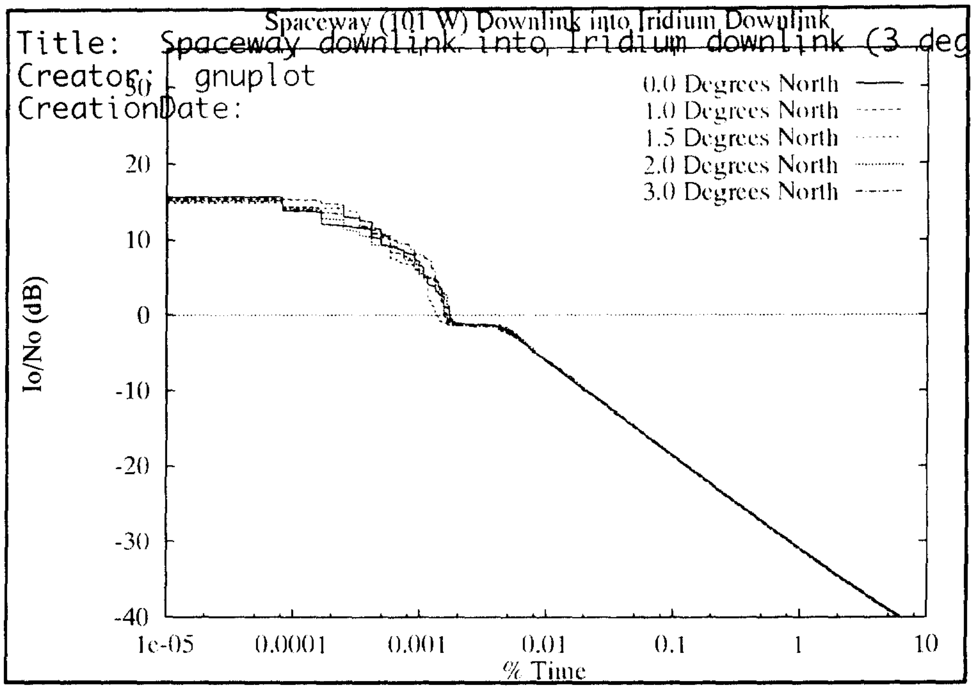


Figure 13. I_0/N_0 for SPACEWAY downlink into IRIDIUM downlink.

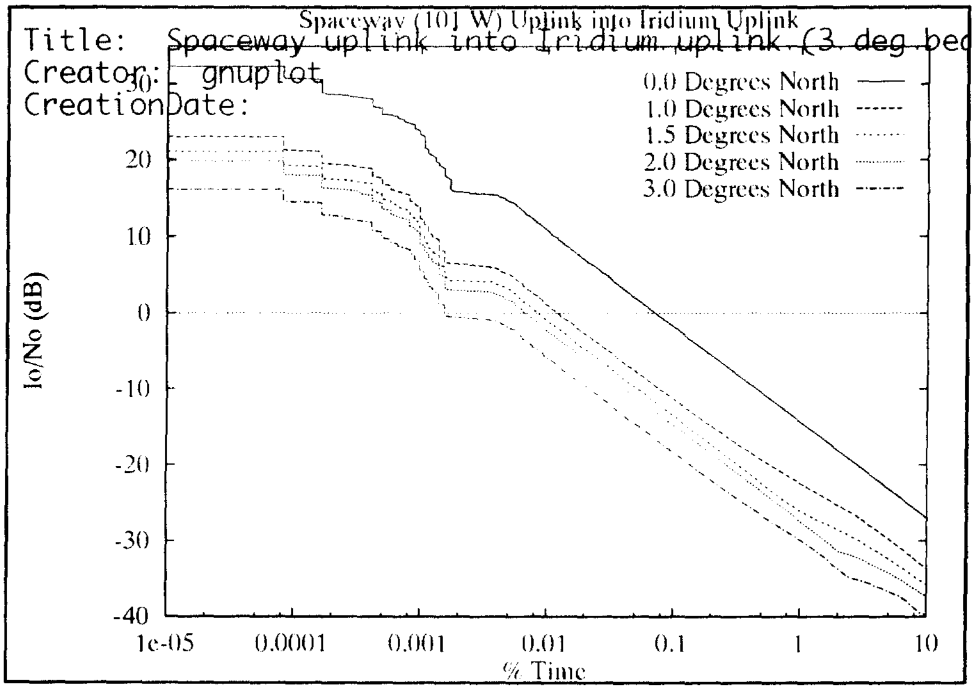


Figure 14. I_0/N_0 for SPACEWAY uplink into IRIDIUM uplink.

3

APPENDIX 3

A REVIEW OF IRIDIUM® FEEDER LINK SELECTION CRITERIA

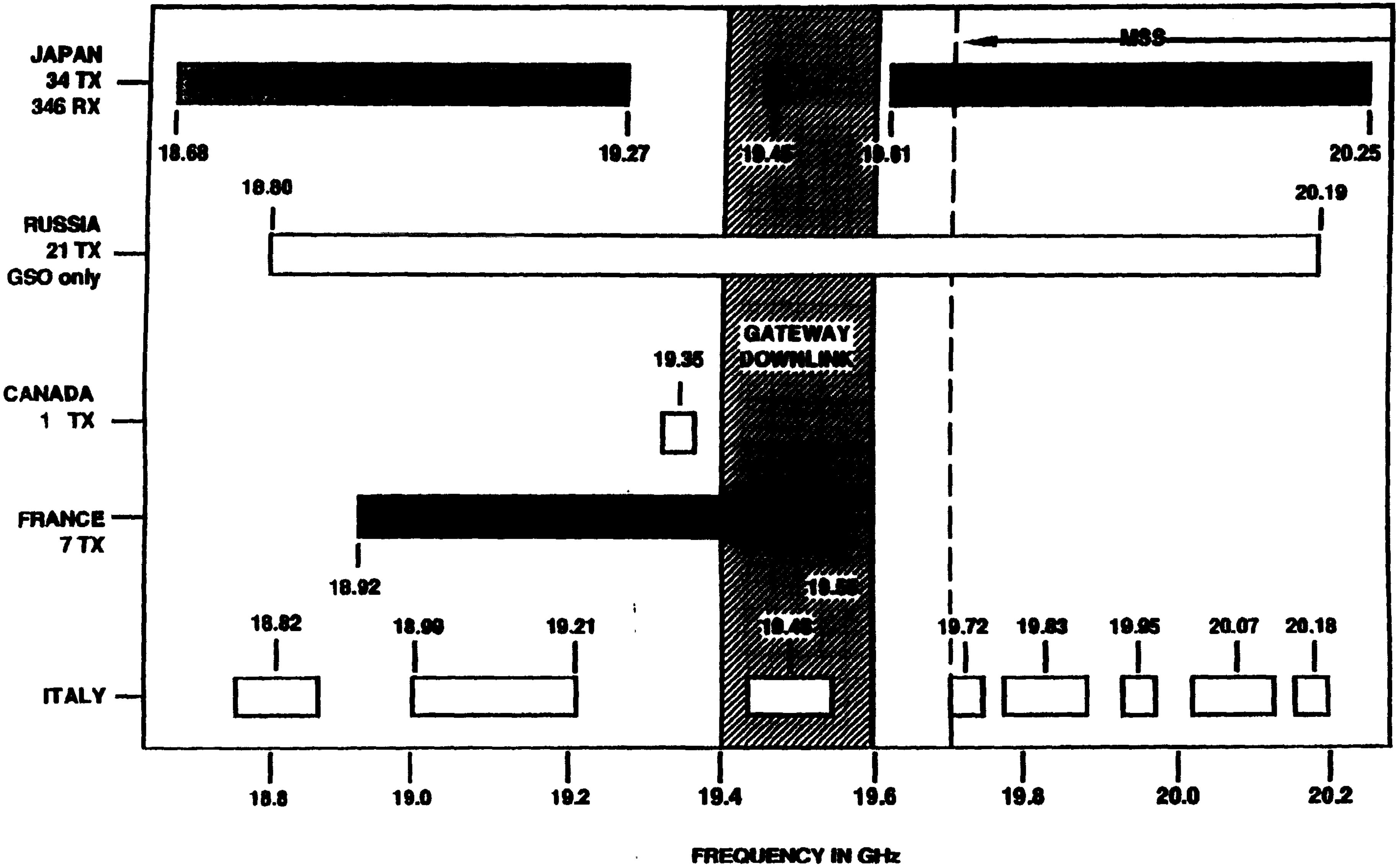
The IRIDIUM® feeder link downlink tuning band was selected to minimize coordination problems worldwide. Comments received from various administrations on the HIBLEO Advance Publication (Appendix 4) indicated a concern for protecting the GSO use of the fixed-satellite service (FSS). In response to these concerns, the specific downlink frequencies were selected so as to avoid existing GSOs to the extent possible.

Based upon analysis of registered users on both the BR and FCC data bases, IRIDIUM® filed with the BR (through the FCC) for the band 19.4 to 19.6 GHz for the feeder link downlink. Figure 1 depicts the "Worldwide K-Band FSS Registration" situation at that time. From a coordination perspective, primary consideration was given to selecting a 200 MHz tuning band that avoids worldwide space stations and minimizes the number of fixed microwave stations with which coordination would be necessary.

One potential problem worldwide that was a significant factor in the selection of the feeder link downlink tuning band was the recent allocation at WARC-92 of primary status to mobile satellite service (MSS) above 19.7 GHz. The argument for operation below 19.7 GHz is to avoid the band used by mobile units that will be roaming about the countryside. The coordination process with mobile units is complicated by the very nature of their service, in that their location is unpredictable. Operations below the 19.7 GHz band segment will isolate IRIDIUM® from the MSS band, and provide a degree of protection from other sources by operating in a band with Power Flux Density (PFD) limits especially since it was expected that the band 19.7-20.2 GHz would be preferred by FSS-GSO satellite networks because of the lack of a PFD limit.

WORLDWIDE K-Band FSS REGISTRATION*

18.8 to 20.2 GHz



*CURRENT IFRB REGISTRATION FOR SATELLITE STATIONS

FIGURE 1

On the other hand, the PFD limit does not grant IRIDIUM® protection from fixed stations. Since IRIDIUM® feeder links will be operating at elevation angles of as low as 5 degrees above the horizon, it is prudent to avoid these fixed stations if possible. There are 5,724 registered fixed microwave users in the 18.8 to 20.2 GHz band (both transmit and receive) in the United States. With the objective of avoiding fixed microwave stations, the band from 19.4 to 19.6 GHz is preferable, at least in the United States.

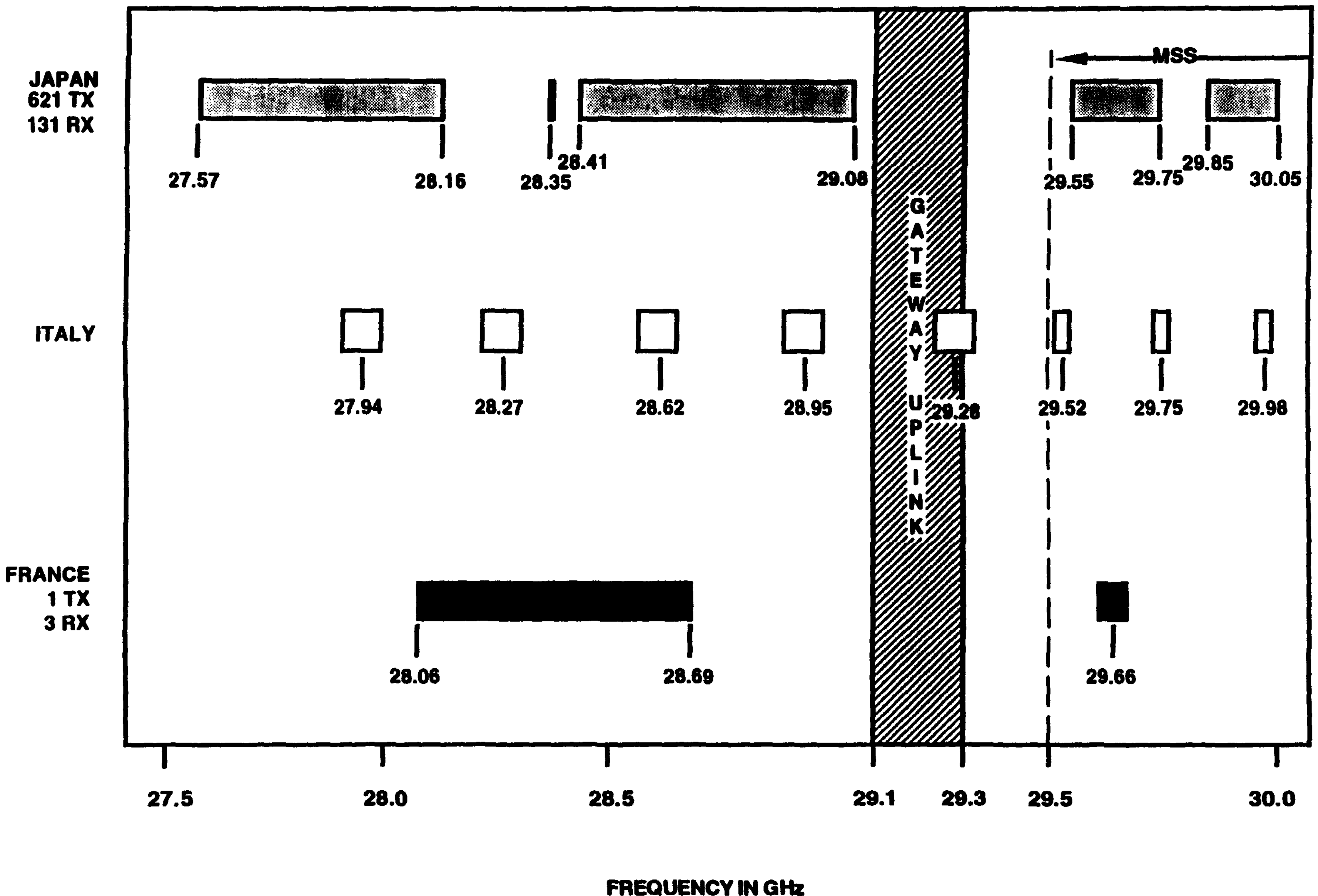
Although there is still a fairly large number of terrestrial users (365) registered in the United States between 19.4 to 19.6 GHz, this is mitigated by the fact that there is a PFD limit below 19.7 GHz (RR 2578). This has the effect of both limiting the power from other selected space services (RR 2579), and alleviating coordination problems as long as IRIDIUM® can prove it is operating below the limit.

The uplink tuning band was also selected to minimize coordination problems worldwide. Figure 2 depicts the "Worldwide Ka-Band FSS Utilization" situation at that time. The recent allocation at WARC-92 of primary status to MSS above 29.5 GHz presented problems for the uplinks similar to those for the downlinks. The argument for operation below 29.5 GHz is to avoid the band used by the MSS antennas. These mobile units could conceivably be located in close proximity to the IRIDIUM® Gateways, and transmitting at a high flux density. The ITU Radio Regulations allow such units to operate with an unrestricted EIRP for angles of elevation that exceed 5 degrees above the horizon (RR 2543). It was further expected that GSO systems would use the band 29.5-30 GHz.

To avoid global coordination problems with existing GSO systems, the selected tunable band was placed between bands registered by Italy and Japan in an effort to avoid overlap as much as possible. The selected tuning band of 29.1 to 29.3 GHz also avoids coordination problems with fixed terrestrial stations. The FCC

WORLDWIDE Ka-Band UTILIZATION*

27.5 to 30.0 GHz



*CURRENT IFRB REGISTRATION SATELLITE AND TERRESTRIAL STATIONS

FIGURE 2

database shows 54 U.S. stations in the 27.5-29.5 GHz band (15 in the 27.5-28.0 GHz band, 26 in the 28.5-29.0 GHz band, and 13 in the 29.0-29.5 GHz band).

In summary, the particular 20/30 GHz FSS allocations proposed for the IRIDIUM® system feeder links were selected 1) because of the apparent light use; 2) because of the need to minimize coordination problems; and 3) because of IRIDIUM® system design considerations. Modification of these frequencies would result in adverse delay in the coordination of IRIDIUM® Gateways and would require significant redesign, thereby delaying implementation of the system.

ENGINEERING CERTIFICATE

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in these Comments and the Technical Appendix hereto, that I am familiar with Part 25 of the Commission's Rules, that I have either prepared or reviewed the engineering information submitted in these Comments and Technical Appendix, and that it is complete and accurate to the best of my knowledge and belief.

David Carroll

Title: Technical Staff Engineer
Spectrum and Standards
Motorola Satellite Communications

Date: August 23, 1995

CERTIFICATE OF SERVICE

I, Colleen Sechrest, hereby certify that copies of the foregoing Comments of Motorola Satellite Communications, Inc. and Iridium, Inc. filed in CC Docket 92-297 were served by hand delivery, this 7th day of September, 1995, on the following persons:

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